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Effects of Dowicide® G-ST on Development of Experimental Estuarine Macrobenthic Communities

M.E. TAGATZ, J.M. IVEY and M. TOBIA

Abstract—Aquaria containing clean sand received a continuous supply of flowing seawater from Santa Rosa Sound, Florida, mixed with known quantities of Dowicide® G-ST (79% sodium pentachlorophenate) for thirteen weeks. The measured concentrations of pentachlorophenol (PCP) in the aquaria were 1.8, 15.8 and 161 μg/l. At the end of the experiment, macrofauna established in control and experimental aquaria was examined. Mollusks, arthropods and annelids were numerically dominant among the macrofauna. Although exposure to 1.8 μg PCP/l had no effect, the higher concentrations of PCP caused marked reduction in the numbers of individuals and species. Mollusks were the most sensitive taxonomic group to PCP. These results and our previous studies on the effects of a nine-week exposure to PCP on the establishment of macrobenthic communities indicate that discharge of PCP into natural waters could alter the normal colonization by benthic animals and could impact various ecological relationships among localized populations.

Introduction

The extensive use of pentachlorophenol (PCP) as a wood preservative and as a biocide in a variety of industries threatens the aquatic environment. PCP has been

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TABLE 1. Animals Collected from Control Aquaria and from Aquaria Exposed to Dowicide® G-ST for 13 Weeks

Animal	Control		PCP concentration (μg/l)[a]					
			1.8		15.8		161	
Mollusca								
Enis minor	987	(10)[b]	1156	(10)	695	(10)	0	(0)
Mulina lateralis	45	(9)	59	(10)	26	(8)	0	(0)
Polinices duplicatus	6	(3)	5	(4)	4	(4)	0	(0)
Cyrtopleura costata	0	(0)	1	(1)	0	(0)	0	(0)
Lyonsia hyalina floridana	1	(1)	0	(0)	0	(0)	0	(0)
Doridella obscura	1	(1)	0	(0)	0	(0)	0	(0)
Diastoma varium	1	(1)	0	(0)	0	(0)	0	(0)
Arthropoda								
Balanus amphitrite niveus	352	(10)	301	(10)	275	(10)	0	(0)
Corophium acherusicum	26	(5)	53	(7)	15	(6)	0	(0)
Callinectes similis	1	(1)	0	(0)	3	(2)	2	(2)
Idoteidae	0	(0)	0	(0)	1	(1)	0	(0)
Annelida								
Polydora ligni	310	(10)	293	(10)	230	(10)	11	(4)
Neanthes succinea	22	(9)	31	(9)	18	(7)	24	(8)
Heteromastus filiformis	0	(0)	0	(0)	22	(6)	0	(0)
Spiophanes bombyx	7	(4)	5	(2)	3	(3)	0	(0)
Armandia agilis	1	(1)	2	(2)	2	(2)	0	(0)
Armandia maculata	2	(1)	1	(1)	0	(0)	0	(0)
Polydora websteri	4	(2)	2	(2)	1	(1)	0	(0)
Capitellides jonesi	0	(0)	0	(0)	1	(1)	1	(1)
Streblospio benedicti	1	(1)	0	(0)	2	(1)	0	(0)
Eumida sanguinea	2	(2)	0	(0)	2	(2)	0	(0)
Eteone heteropoda	1	(1)	0	(0)	0	(0)	0	(0)
Mediomastus californiensis	0	(0)	1	(1)	1	(1)	0	(0)
Polydora socialis	0	(0)	3	(2)	0	(0)	0	(0)
Polydora aggregata	0	(0)	0	(0)	1	(1)	0	(0)
Nemertea								
Nemertea	7	(4)	10	(4)	9	(6)	0	(0)
Coelenterata								
Actinaria	4	(2)	1	(1)	6	(3)	0	(0)

TABLE 1. continued

Animal	Control		PCP concentration (μg/l)[a]					
			1.8		15.8		161	
Chordata								
Atherinidae	2	(1)	0	(0)	0	(0)	0	(0)
Molgula manhattensis	0	(0)	1	(1)	0	(0)	0	(0)
Echinodermata								
Leptosynapta inhaerens	0	(0)	1	(1)	0	(0)	0	(0)
Sipunculoidea								
Sipunculoidea	0	(0)	1	(1)	0	(0)	0	(0)
Platyhelminthes								
Polycladida	0	(0)	1	(1)	0	(0)	0	(0)

[a]Measured concentration in the water
[b]Number of aquaria from which the animals were collected.

released into natural waters from industrial and agricultural operations and from runoff waters (Adelman *et al.*, 1976). There have been reports of toxic concentrations of PCP in aquatic environments (Fountaine *et al.*, 1976; van Dijk *et al.*, 1977). The available information indicates that PCP is toxic to a variety of aquatic organisms (Becker and Thatcher, 1973). However, relatively little is known of the effects of PCP and its salts on marine and estuarine organisms. Of particular concern is the use of PCP derivatives such as Dowicide® G-ST (79% sodium pentachlorophenate) in the expanding exploration for oil in the marine environment. These compounds are used as bactericides in drilling and completion fluids for oil-well drilling (Robichaux, 1975).

We initiated studies to determine the effects of PCP and its derivatives on the development of estuarine macrobenthic communities. We previously reported effects of a continuous nine-week exposure to concentrations of 7, 76 and 622 μg PCP/l on establishment of macrofauna in an experimental flow-through system (Tagatz *et al.*, 1977). We have since investigated the effects of exposure to Dowicide® G-ST for thirteen weeks on the establishment of macrobenthic communities, and results are presented here.

Experimental System

The experimental design (Hansen, 1974) consisted of 10 control aquaria and 10 aquaria for each of three concentrations of the toxicant. Aquaria (56 cm long, 9 cm wide, and 12 cm high) were filled to a depth of 6 cm with sand dredged from Santa Rosa Sound, Florida. The water levels were maintained at 9 cm (3 cm above substratum).

Unfiltered seawater with its constituent plankton was pumped from Santa Rosa Sound to overflow constant-head boxes, one for the control and one for each test concentration. Ten small standpipes within each of these boxes continually supplied water to the aquaria at a rate of 200 ml/min (maintained by adjusting the height of a 3.2 mm diameter hole in each standpipe). Dowicide® G-ST dissolved in deionized water was metered (by pump) into and mixed with the seawater in the constant-head boxes. Aquaria were exposed to the toxicant for thirteen weeks, December 27, 1976 - March 28, 1977. Water flowed from the aquaria through notched end-openings. Large animals, such as crabs, could escape through these openings before their number could drastically affect community structure.

At the end of exposure, the animals were collected by siphoning contents of the aquaria into a 1-mm mesh sieve, preserved and identified. Analysis of variance and the Student-Newman-Keul tests were used to test the statistical significance of differences in numbers and species of animals among control and exposed aquaria.

Concentrations of PCP in test water and sediment were determined by gas chromatography (Tagatz *et al.*, 1977; Schimmel *et al.*, this symposium) Samples of water were taken twice a week from the constant-head boxes, and sediment cores were taken from 3 of 10 aquaria per concentration at the end of exposure. Limits of detection were 0.2 μg PCP/l in seawater and 2.5 μg PCP/kg (dry weight) in sediment. Recoveries averaged greater than 80% for water and sediment samples.

The averages and ranges of PCP concentrations measured in water were 1.8 μg/l (0.5-4.1), 15.8 μg/l (8.9-22.0), and 161 μg/l (135-230). No PCP was detected in water samples from the control aquaria. The sediment samples from control aquaria and aquaria exposed to 1.8 μg PCP/l did not contain detectable amounts of PCP. A range of 3 to 6 μg PCP/kg was found in sediment from aquaria exposed to 15.8 μg PCP/l; 41 to 71 μg PCP/kg was found in sediment from aquaria exposed to 161 μg PCP/l.

Macrobenthic Communities

At the end of the 13-week period, the experimental and control aquaria contained a total of 5,066 animals, representing 32 species of 9 phyla (Table 1). The three most abundant species were the clam, *Enis minor* (2,838), the barnacle, *Balanus amphitrite niveus* (928), and the polychaete, *Polydora ligni* (844). The numerically dominant phyla were Mollusca, Arthropoda and Annelida.

The abundance of animals was affected by PCP (Figure 1). Total numbers of animals and species (Table 2) were significantly fewer ($P < 0.01$) in aquaria exposed to 161 μg/l than in control aquaria and aquaria exposed to lower concentrations of the toxicant. The number of animals in aquaria exposed to 15.8 μg/l also differed significantly from those in control aquaria and aquaria exposed to 1.8 μg PCP/l.

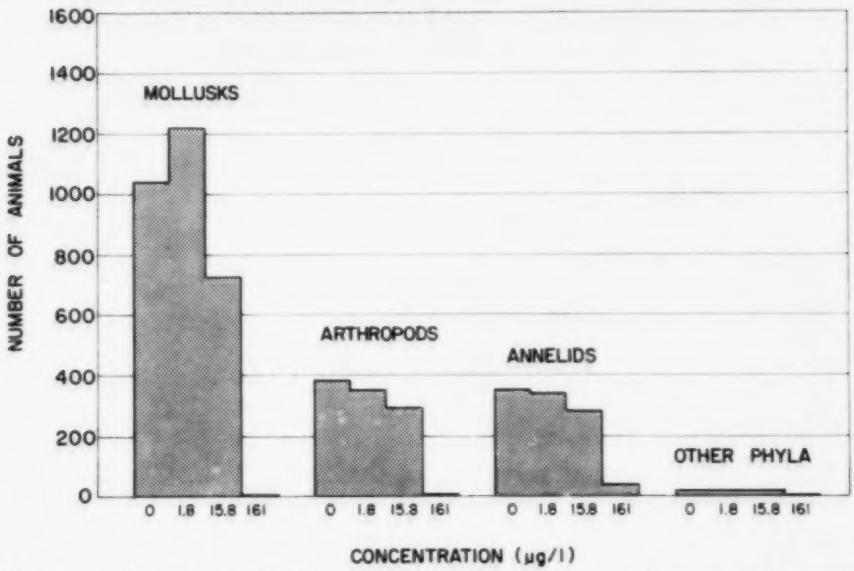

Figure 1. Number of animals, by phylum, collected from control aquaria and aquaria exposed for 13 weeks to Dowicide® G-ST. The average measured concentrations of PCP in the water from experimental aquaria were 1.8, 15.8 and 161 µg/l. The control aquaria did not contain detectable amounts (detection limit 0.2 µg/l) of PCP.

Mollusks were most affected by PCP. Although the number of individuals of arthropods and annelids decreased at 15.8 µg/l, only mollusks were significantly fewer than in control aquaria. This relative sensitivity of developing estuarine mollusks to PCP was also noted in our previous studies (Tagatz *et al.*, 1977). These results are consistent with the known molluscicidal applications of PCP (Bevenue and Beckman, 1967).

Exposure to concentrations of PCP such as 76 µg/l (Tagatz *et al.*, 1977), 161 µg/l (this study) and 622 µg/l (Tagatz *et al.*, 1977) caused a reduction not only in the number of individuals but also in the number of macrobenthic species in the experimental flow-through system. Changes in the relative abundance of species within a taxonomic group were also noted. For example, exposure to 161 µg PCP/l reduced the relative abundance of the polychaete worm, *Polydora ligni*, but not that of *Neanthes succinea*.

Conclusions

Discharges of PCP and its derivatives in nature, at levels tested in the laboratory, could disrupt stable ecological relationships among localized populations and have a direct adverse effect on abundance of various species normally

TABLE 2. Relative Abundance (Number of Individuals and Species) of Various Phylogenetic Groups from Control Aquaria and Aquaria Exposed to Dowicide® G-ST for 13 Weeks

Phylum	Control		PCP concentration (μg/liter)[a]					
			1.8		15.8		161	
	No.	Sp.	No.	Sp.	No.	Sp.	No.	Sp.
Mollusca	1041	6	1221	4	725[b]	3	0[b]	0[b]
Arthropoda	379	3	354	2	294	4	2[b]	1[b]
Annelida	350	9	338	8	283	11	36[b]	3[b]
Nemertea	7	1	10	1	9	1	0	0
Coelenterata	4	1	1	1	6	1	0	0
Chordata	2	1	1	1	0	0	0	0
Echinodermata	0	0	1	1	0	0	0	0
Sipunculoidea	0	0	1	1	0	0	0	0
Platyhelminthes	0	0	1	1	0	0	0	0
TOTAL	1783	21	1928	20	1317[b]	20	38[b]	4[b]

[a]Average measured concentration in the water
[b]Significantly less ($P < 0.01$) than control; significance is indicated only for the three most abundant phyla.

colonizing the substratum. For example, changes in the relative abundance of polychaete worms, a large group important in marine food webs, would impact many predator-prey interactions. Also, these compounds could decrease abundance of various commerically important species of arthropods and mollusks.

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